

2006 Minerals Yearbook

KYANITE AND RELATED MATERIALS

Kyanite and Related Materials

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Kyanite and mullite (calcined kyanite) output in the United States was an estimated 90,000 metric tons (t) in 2006; the United States continued to be the world's leading producer of the mineral (table 3). Production of synthetic mullite in the United States was an estimated 40,000 t. There was no reported U.S. production of sillimanite. Andalusite was mined and marketed as part of a mineral mixture in the United States, but data are withheld to avoid disclosing company proprietary data. Refractory products continued to be a major end use for kyanite and related materials.

This report includes information on andalusite, kyanite, and sillimanite (all of which have the formula Al₂SiO₅), and mullite and synthetic mullite (Al₆SiO₁₃). Mullite can occur, although rarely, as a natural mineral. Most commonly, it can be made by calcining kyanite at high temperature (for example, above 1,450° C). By contrast, synthetic mullite in this report refers to mullite that is made by calcining at high temperature certain mixtures of alumina- and silica-containing minerals and materials such as bauxite and kaolin.

Production

Kyanite Mining Corp. (KMC), the sole U.S. producer of kyanite and kyanite-derived mullite, operated two open pit mines in Buckingham County, VA, and beneficiated the ore into a marketable kyanite concentrate. The company also had two kilns at its Dillwyn, VA, facility for production of mullite from kyanite. Reported U.S. production data collected by the U.S. Geological Survey (USGS) are withheld to avoid disclosing company proprietary data. The estimate of U.S. kyanite production of 90,000 t was based on nongovernment estimates from previous years; the estimated value of the material in 2006 was about \$14 million. KMC calcined some of its kyanite to yield mullite, a refractory (heat-resistant) material. KMC's mullite product contained about 80% mullite (Kyanite Mining Corp., 2006). Synthetic mullite, made from calcined bauxitic kaolin and sold by C-E Minerals, Inc., contained 87% mullite and was produced near Americus, GA (C-E Minerals, 2006). Based on nongovernment estimates from previous years, estimated U.S. production of synthetic mullite was about 40,000 t in 2006; the estimated value for the material was about \$10 million.

Piedmont Minerals Co., Inc. in Hillsborough, NC, mined a deposit containing and alusite combined with pyrophyllite and sericite. The company sold products containing blends of the three minerals to producers of ceramics and refractories.

Consumption

Kyanite increases in volume by 16% to 18% when calcined to mullite and can be used in its raw concentrate form in a

refractory mixture to offset the shrinkage on firing of other components, especially clays. Mullite is abrasion- and slag-resistant. It also has good creep resistance, which is resistance to physical deformation under load at high temperatures. Andalusite expands irreversibly by only about 4% to 6% when calcined, and can, therefore, be used directly in refractories in its raw state (Dickson, 2006; Lasseter, 2006). In other refractory applications, kyanite concentrate is calcined to mullite before being added to refractory mixes if the volume increase of the kyanite is not required in the mix (Roskill Information Services Ltd., 1990, p. 56).

Examples of refractories that contain andalusite, kyanite, or mullite include insulating brick, firebrick, kiln furniture, refractory shapes, and monolithic refractories (made of a single piece or as a continuous structure) including castables (refractory concrete), gunning mixes, mortars, plastics, and ramming mixes. When added to a refractory or ceramic body, the particle structure of andalusite, kyanite, or mullite gives an interlocking quality and added mechanical strength. According to an industry source, kyanite is more commonly used in a refractory product's matrix with fine grains, and andalusite is commonly used with both fine and coarse grains (Backus, 2006). Other end uses of kyanite and related materials include brake shoes and pads, electrical porcelain, foundry use, precision casting molds, sanitaryware, and other products (Kyanite Mining Corp., 2006).

Monolithic refractories are a major end use of kyanite and are supplied in unfired, generally unshaped form in contrast to prefired, preshaped brick products. They include a wide variety of products that may be gunned, hand packed, moulded, poured, pumped, rammed, or vibrated into place. Monolithic refractories are used in many of the same consuming industries as brick, including aluminum furnaces, cement production (certain aspects), foundry (both ferrous and nonferrous), iron and steel production, petrochemicals, power generation, and other applications (Moore, 2004).

Iron and steel production continued to be the leading user of refractories worldwide. U.S. raw steel production increased by about 3.5% in 2006 from that of 2005 (American Iron and Steel Institute, [undated], p. 73), which is favorable for the kyanite and refractories market.

Prices

Prices for marketable kyanite have been published infrequently in trade journals in recent years. According to Sweet and others, 2006, prices for marketable kyanite concentrate, free on board, Virginia, were \$149 to \$196 per metric ton, based on particle size.

Foreign Trade

An estimated one-third of U.S. kyanite and mullite was exported to countries in Europe, Latin America, the Pacific rim, and other areas. Most of the material imported into the United States in 2006 was from South Africa and was presumed to be andalusite (table 2). No known U.S. imports of kyanite or sillimanite were reported in 2006.

World Review

South Africa continued to be the leading producing country of andalusite, with an estimated 230,000 t in 2006. France produced an estimated 65,000 t of andalusite. Although China appears to be a producer of kyanite and related minerals (Dickson, 2006), the USGS has not obtained official production data. Using available data, India has been the predominant producer of sillimanite, with an estimated 14,000 to 15,000 t/yr in recent years. Countries that are said to be producers of synthetic mullite (sintered mullite and/or fused mullite) include Brazil, China, Germany, Hungary, and Japan (Taylor, 2005).

China.—As is true worldwide, the steel industry is the major consumer of refractories in China, with an estimated 70% of the country's annual refractories market being used for the production of steel. Although there may be up to 2,000 refractory companies in China, ongoing restructuring may contribute to reducing the number of companies (Semler, 2006b).

Continuing development of higher-performance refractories is recognized as important in improving the service lives of refractories. Corresponding improvements in the development and production of ingredients for refractories have included high temperature sintering or electro fusing of certain natural minerals and other additives to produce synthetic refractory ingredients. Jiangdu New Jinghui Special Refractories Co. Ltd. (JJSRC) is a manufacturer of such materials, including a series of sintered mullites. These synthetic mullites have varying alumina content. Raw materials for these synthetic mullites include high-grade kaolin from Suzhou in China's southeastern Jiangsu province and imported commercial alumina. The synthetic mullites are used for hot blast stoves, thermal shock resistant low creep bricks, castables, and kiln furniture (Li and Zhang, 2006).

India.—The refractories industry was under severe pressure from 1998 to 2002, because of depressed conditions in the steel industry and growing competition from domestic and overseas suppliers of refractories. However, since 2003, growth in output and rate of capacity utilization of refractories have significantly improved (Industrial Minerals, 2006).

The steel and cement industries consume 74% and 12%, respectively, of the annual production of refractories. The glass, nonferrous metals, and ceramics industries consume the remainder. Refractory consumption in the steel industry is about 12 to 14 kilograms per ton (kg/t) of steel. (The world's lowest unit consumption, 7.5 kg/t, is in Japan). However, with continually improving refractories and practices worldwide, the unit consumption per ton of steel in India (and other countries) is projected to decrease (Semler, 2006c).

Outlook

Global iron and steel production, the largest consumer of refractories, increased by about 9% more than that of 2005. The four leading steel-producing countries and their share of 2006 steel output were China, 34%; Japan, 9%; the United States, 8%; and Russia, 6% (International Iron and Steel Institute, 2007). Markets for cement, chemicals, and energy also boosted refractories demand around the world (Grahl, 2006). According to preliminary estimates, world apparent steel use in 2007 may increase by 5% more than that of 2006 (International Iron and Steel Institute, 2006). World steel production has been shifting from Japan, North America, and western Europe to Asia. China has had significant expansion in steel output along with growth in its domestic refractories industry.

Issues concerning producers and suppliers of refractory raw materials include the cost of energy; increases in raw materials prices; and transportation and supply issues, including rising freight costs (Semler, 2006a). A long-term trend is the drive to improve refractories in order to lower refractory consumption per ton of steel produced. Higher performance refractory products with longer life cycles facilitate higher quality-end products for the steelmaker and reduce production and operating costs. Potential issues facing refractory producers include shifting of production to developing countries and consolidation in the industry (Taylor, 2006). Companies are focusing on cost-reduction measures and product innovations to ensure continued profitability (Grahl, 2006).

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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

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Kyanite and Related Minerals. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Kyanite and Related Minerals. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1 PRICE OF KYANITE AND RELATED MATERIALS IN 2006

(Dollars per metric ton)

	Price
Andalusite, free on board, Transvaal, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk lots	238-277
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 18-ton lots	282-343

Source: Industrial Minerals, no. 471, December 2006, p. 75.

TABLE 2 $\mbox{U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE,} \\ \mbox{KYANITE, AND SILLIMANITE}^{1,\,2,\,3}$

	Quantity	Value ⁴	
Year	(metric tons)	(thousands)	
2005	6,300	\$2,410	
2006	4,350	1,580	

¹Most material is and alusite from South Africa. No known kyanite or sillimanite imports were reported.

Source: U.S. Census Bureau.

²Harmonized Tariff Schedule of the United States code 2508.50.0000.

³Data are rounded to no more than three significant digits.

⁴Customs value.

 ${\it TABLE~3}$ KYANITE AND RELATED MINERALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY $^{1,\,2}$

(Metric tons)

Country and commodity ³	2002	2003	2004	2005	2006
Australia:					
Kyanite	1,000	1,000	1,000	1,000	1,000
Sillimanite ⁴	300	300	300	300	300
Brazil, kyanite, marketable	600	600	600	600	600
China, unspecified	3,200	3,200	3,300	3,400	3,400
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	6,000	6,000	6,200	6,800	7,000
Sillimanite	14,000	14,000	14,500	15,000	15,000
South Africa, andalusite	165,087 5	164,921 5	234,625 5	228,375 r, 5	230,000
Spain, andalusite	r	r	r	r	
United States:					
Kyanite	90,000	90,000	90,000	90,000	90,000
Mullite, synthetic	40,000	40,000	40,000 6	40,000	40,000
Zimbabwe, kyanite	5,657 ⁵	745 ⁵	210 5		

^rRevised. -- Zero.

¹U.S. and estimated data are rounded to no more than three significant digits.

²Owing to incomplete reporting, this table has not been totaled. Table includes data available through April 13, 2007.

³In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

 $^{^4}$ In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) that contains 40% to 48% A $_2$ O is produced.

⁵Reported figure.

⁶Source: Dickson, Ted, 2006, Sillimanite minerals, *in* Countries and commodities report: Mining Journal. (Accessed March 17, 2006, via URL http://www.mining-journal.com.)